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The interaction of Energy Consumption and Economic Growth in South Africa: Assessment from the Bounds Testing Approach.

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THE INTERACTION OF ENERGY CONSUMPTION AND ECONOMIC GROWTH IN SOUTH AFRICA: ASSESSMENT FROM THE BOUNDS TESTING APPROACH

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Abstract: Researchers concur that energy plays a very significant role in the economic growth and development of any country and that increasing access to modernized systems of energy is critical to unlocking enhanced economic and social development in any country. In the light of this, the current article has empirically examined the causal interactions between energy consumption and economic growth in South Africa for the period 1970 to 2015 using the ARDL-bounds testing method. The results show that all the variables were found to be integrated of order one. The empirical results obtained fully support a positive long-run cointegrating relationship between real economic growth and energy consumption in South Africa. The article used trade openness and financial development as control variables in the model. The research found that although there is unidirectional causality running from energy consumption to economic growth in the short-run, there is long-run bidirectional causality between the two variables as indicated by the coefficients of the error correction terms which were found to be negative and significant as predicted by theory. This means that reducing energy consumption adversely affect real economic growth in both the short- and the long-run; thus, South Africa should adopt a more vigorous energy policy.

Keywords: Energy consumption; economic growth; financial development; trade openness; ARDL; error-correction model; South Africa

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1. INTRODUCTION

The debate on the interaction of energy consumption and economic growth is far from being over given the fact that there is no consensus on the direction of causality between energy consumption and economic growth even in a developing country like South Africa. Many studies have been carried out on the energy consumption and the economic growth nexus using various data frequencies, countries, groups of countries, methodologies and periods and a whole gamut of varied results has been obtained. This obviously implies that there is still need for further investigation on the energy consumption-economic growth nexus.

It should be noted that economic growth is among the most crucial factors to be considered in projecting changes in world energy consumption (Saidi *et al*.,2017; Eggoh *et al*., 2011). It is for this reason that the analysis of the relationship between energy consumption and economic growth has attracted a lot of attention during last two decades. In fact, the scenario where economic growth promotes energy consumption or vice versa has aroused research interest among policymakers and economists. It should be noted that over the two last decades, a large body of published research has been produced investigating the causal nexus between energy consumption and economic growth. This stems from the fact that the direction of causality has important and significant policy implications. If energy consumption is a significant component in economic growth, energy conservation policies that reduce energy consumption may negatively influence real GDP (Eggoh *et.al,* 2011; Saidi *et.al,* 2017). In fact, a unidirectional causality running from economic growth to energy consumption connotes less energy dependency by the economy, which implies that energy conservation policies may be implemented with negligible or no negative effect on economic growth GDP (Eggoh *et.al,* 2011; Saidi *et.al,* 2017). It should be noted that recent empirical studies on the energy consumption-economic growth nexus in African countries have failed to reach a consensus as to the direction of causality. Most of these studies have used various econometrics approaches in their analysis (see Odhiambo, 2009, 2010, 2016; Kebede *et al*., 2010; Al-Mulali and Sab, 2012; Omri, and Kahouli, 2014; Iyke, 2015; Shahbaz *et al*., 2017; Ranjbar *et al*., 2017; Kumar *et al*., 2015; Salahuddin *et al*., 2015; Hassom and Masih, 2017; Bah and Azam, 2017; Dlamini *et al*., 2015, 2016; Menyah and Wolde-Rufael, 2010). Al-Mulali and Sab (2012) also found that, at the country level, feedback long-run positive relationship between the trade variables, energy consumption and CO_2 emission takes place generally when the share of trade in GDP is high and when the country's level of development is high. On the other hand, negative or insignificant long-run relationship generally exists in the countries that have a smaller share of trade in GDP and when these countries are in early stages of development.

The current study applies a relevant methodology that has often produced consistent and reliable results. In addition, the study employs more recent data than previous similar studies. The study, therefore, tests the hypotheses that energy consumption does not Granger cause economic growth; and that economic growth does not Granger cause energy consumption.

The rest of the article is organised as follows: Section 2 reviews the literature. Section 3 discusses methodological issues and data description and Section 4 discusses the empirical results. Finally, the conclusions and policy recommendation are presented in Section 5.

2. BRIEF EMPIRICAL LITERATURE

2.1 Empirical literature on other countries

Many studies have been carried out in both the developed, developing countries and the results obtained vary a lot, and there is no consensus on the causal relationship between energy consumption and economic growth across different studies. Many studies have established that energy consumption is positively related and/or Granger causes economic growth (see Kebede *et.al,* 2010; Omri, and Kahouli, 2014; Al-Mulali and Sab, 2012; Shahbaz *et.al,* 2017; Iyke, 2015).

In addition, some studies found that economic growth has positive effects and/or Granger causes energy consumption. Ozturk *et al*. (2010) used panel data and found that there is long-run unidirectional causality from GDP to energy consumption in low- income countries, bidirectional causality between energy and economic growth in middle- income countries and a weak relationship when all the countries are considered collectively. Moreover, Omri, and Kahouli (2014) established that economic growth Granger causes energy consumption in some countries they studied. Next, Hossain (2011) studied newly industrialised countries and found no evidence of long-run causality between economic growth and energy consumption, but unidirectional causality running from economic growth to energy consumption and from trade openness to economic growth. In a related study, Sebri and Ben-Salha (2014) analysed BRICS countries using VECM and found bidirectional causality between economic growth and renewable energy consumption. In another related study Keho (2016) investigated 12 African countries and found that economic growth and industrial output have positive effects in energy consumption in most of the countries. Additionally, Aïssa *et al.* (2014) examined the relationship between output, renewable energy consumption and trade in Africa and found that in the short-run, there is no causality between renewable energy consumption and trade or output. However, in the long- run renewable energy consumption and trade have a statistically significant positive impact on output.

Some of the studies attempted to find out how financial development interacts with energy consumption and economic growth. First, Al-Mulali and Sab (2012) found that energy consumption affects financial development in all the countries investigated. Second, Khan *et al*. (2014 found bidirectional causality between energy consumption and financial development. Third, Shahbaz *et al*. (2017) studied India and found that shocks to financial development significantly affect economic growth and that there is no causality between energy consumption and financial development. Fourth, Khan *et al.* (2017) analysed the relationship between financial development and energy consumption and found mixed results that changed from country to country and from region to region. Fifth, Ahmed (2017) studied the role of financial development for the energy-growth-trade nexus in BRICS economies and found that all the variables have a long-run relationship. In addition, he found that BRICS′ economic growth increases the demand for energy and that financial development and trade provides a sustainable development path.

Sixth, Paul and Bhattacharya (2004) examined the causal relations between energy consumption and economic growth in India. They found bi-directional causality between energy consumption and economic growth. Seventh, Hondroyiannis *et al*. (2002) analysed the empirical relationship between energy consumption and economic growth, for Greece using the vector error-correction model estimation. They found a long-run relationship between the three variables, supporting the endogeneity of energy consumption and real output. Eighth, in another country study Oh and Lee (2004) studied the causal relationship between energy consumption and economic growth using multivariate time series models. Their results found no causality between energy and GDP in the short run and a unidirectional causal relationship running from GDP to energy in the long run. Finally, Ghosh (2002) studied the causality between electricity consumption per capita and Gross Domestic Product (GDP). This study finds the absence of long-run equilibrium relationship among the variables but there exists unidirectional Granger causality running from economic growth to electricity consumption without any feedback effect.

2.2 Empirical literature on South Africa

First, Odhiambo (2010) studied energy consumption, prices, and economic growth in three SSA countries using the ARDL bounds testing procedure and found that the causality between energy consumption and economic growth varies significantly across the countries studied. The results obtained show that for South Africa and Kenya there is a unidirectional causal flow from energy consumption to economic growth. However, in Congo (DRC), economic growth drives energy consumption. Second, comparable results in South Africa were obtained by Menyah and Wolde-Rufael (2010) who employed the ARDL bounds testing procedure and found unidirectional causality running from energy consumption to economic growth. Third, Lin and Wesseh Jr. (2014) employed the non-parametric bootstrap method and found unidirectional causality running from energy consumption to GDP. Fourth, Odhiambo (2016) found unidirectional causality running from economic growth to coal consumption and from coal consumption to employment and bidirectional causality between economic growth and employment.

Fifth, Dlamini *et.al* (2015; 2016) investigated the causality between energy consumption and economic growth using the bootstrap rolling window approach. Their results show that the full-sample Granger causality test revealed no causality between energy consumption and economic growth. However, after allowing for the possibility of structural breaks, they found weak causality between energy consumption and economic growth. Sixth, Bah and Azam (2017) used the ARDL to validate the existence of cointegration between energy consumption and economic growth. They also employed the Toda Yamamoto Granger causality and found no causality between energy consumption and economic growth. Seventh, Hasson and Masih (2017) using ARDL established a positive relationship between energy consumption and economic growth and that electricity prices have a negative effect on electricity consumption and hence economic growth. The study results further show that trade openness and electricity consumption are the leading variables and that the rest are lagging.

Finally, Ranjbar *et.al* (2017) found that energy consumption causes economic growth. When they accounted for structural breaks, economic growth caused energy consumption. In addition, they also found that a reduction in energy consumption reduces economic growth and not vice versa.

3. METHODS AND MODEL SPECIFICATION

3.1 Testing for unit roots

To test the stationarity of the series, the article uses the Augmented Dickey Fuller (ADF) unit root testing procedure (Dickey and Fuller, 1979) and the Phillips Peron (PP) test (Phillips & Perron, 1988). In both the ADF and the PP tests, the size of the coefficient δ_2 is the one that we want to determine in the following equation:

$$\Delta Z_t = \delta_0 + \delta_1 t + \delta_2 Z_{t-i} + \sum_{i=1}^{n} \beta_i \Delta Z_{t-i} + \varepsilon_t \qquad (1)$$

The ADF regression tests for the existence of unit root of Z_t , in all model variables at time t. The variable ΔZ_{t-i} expresses the first differences with n lags and finally ε_t is the variable that adjusts the errors of autocorrelation. The coefficients, δ_0, δ_1, δ_2, and β_i are the ones estimated. The null and the alternative hypothesis for the existence of unit root in variable Z_t is:

$H_0 : \delta_2 = 0$ $\qquad$ $H_1 : \delta_2 < 0$

The other method used to test for unit roots is the Phillips Peron method, which corrects for serial correlation and heteroscedasticity in the error terms by directly modifying the test statistics without including lags (Enders, 2004). Thus, the equations and hypothesis to be tested are similar to the ones for the ADF above except that the lags of the variables are excluded from the models.

$$\Delta Z_t = \delta_0 + \delta_1 t + \delta_2 Z_{t-i} + \varepsilon_t \qquad (2)$$

3.2 Model specification

The empirical literature has provided the basis for the energy consumption and economic growth specifications in this study. Trade openness and financial development have been incorporated in this study as control variables, therefore, they are not interpreted. Data used in the study covers the annual period 1970-2015 (45 observations). Given the small size of the sample, the cointegration relationship among the variables in energy consumption and economic growth models is analysed by using the bounds test proposed by Pesaran *et.al.* (2001). Thus, the long-run equations used in this study can be specified as:

$$LNENEC_t = \delta_0 + \delta_1 LNRGDP_t + \delta_2 LNFD_t + \delta_3 LNTO_t + \mu_{1t} \quad (3)$$

$$LNRGDP_t = \beta_0 + \beta_1 LNENEC_t + \beta_2 LNFD_t + \beta_3 LNTO_t + \mu_{2t} \quad (4)$$

In this case, LNENEC is the logarithm of energy consumption (this refers to electric power consumption and it is measured in kilowatts per hour (kWh)), LNRGDP is the logarithm of real GDP (a proxy for economic growth), LNFD is the logarithm of domestic credit to the private sector (a proxy financial development) and LNTO is the logarithm for trade openness (found by adding exports to imports). From economic theory, the coefficients δ_0, δ_1, δ_2, δ_3, β_0, β_1, β_2, and β_3 are expected to be positive. The bounds test starts from the estimation of unrestricted error correction models (UECMs) of the form:

$$\Delta LNENEC_t = \sigma_1 + \sigma_2 LNRGDP_{t-1} + \sigma_3 LNFDI_{t-1} + \sigma_4 LNTO_{t-1} + \sigma_5 LNENEC_{t-1} + \sum_{i-1}^{p} \sigma_{6i} \Delta LNRGDP_{t-i} + \sum_{i-1}^{p} \sigma_{7i} \Delta LNFDI_{t-i} + \sum_{i-1}^{p} \sigma_{8i} \Delta LNTO_{t-i} + \sum_{i-1}^{p} \sigma_{9i} \Delta LNENEC_{t-i} + v_{1t} \quad (5)$$

$$\Delta LRGDP_t = \theta_1 + \theta_2 LNENEC_{t-1} + \theta_3 LNFDI_{t-1} + \theta_4 LNTO_{t-1} + \theta_5 LNRDGP_{t-1} + \sum_{i-1}^{p} \theta_{6i} \Delta LNRGDP_{t-i} + \sum_{i-1}^{p} \theta_{7i} \Delta LNFDI_{t-i} + \sum_{i-1}^{p} \theta_{8i} \Delta LNTO_{t-i} + \sum_{i-1}^{p} \theta_{9i} \Delta LNENEC_{t-i} + v_{2t} \quad (6)$$

The next step is to calculate the F-statistics following the null hypotheses of no cointegration, that is, H_0: $\sigma_2 = \sigma_3 = \sigma_4 = \sigma_5 = 0$ and H_0: $\theta_2 = \theta_3 = \theta_4 = \theta_5 = 0$ against the alternative hypotheses of cointegration, that is, Ha: $\sigma_2 \neq \sigma_3 \neq \sigma_3 \neq \sigma_5 \neq 0$ and Ha: $\theta_2 \neq \theta_3 \neq \theta_4 \neq \theta_5 \neq 0$. The distribution of the F-statistic developed by Pesaran et.al (2001) is non-standard. The reason is that the F-statistic assumes that series are integrated of order zero and one [I (0), I (1)] and we use the critical bounds tabulated by Narayan (2005) which are more suitable for a small data set. If the calculated F-statistic is less than the lower critical bound (LBC), then the decision about no cointegration may be accepted. Cointegration may be found if the calculated F-statistic exceeds the upper critical bound (UCB). The decision about the long-run relationship is inconclusive if the calculated F-statistic lies between LBC and UBC.

Once cointegration is found then there must be causality at least from one direction. Granger pointed out that existence of cointegration between the variables means that there is information about long- and short-run Granger causality (Shahbaz and Rahman, 2012). Equations (1) and (2) above represent the long-run relationship. However, for policy analysis purposes it is necessary to estimate the short-run equations to capture the speed of adjustment towards long run equilibrium (see Shahbaz and Rahman, 2012: Nyasha and Odhiambo, 2014). The requisite error correction models are specified as follows:

$$\Delta LNENEC_t = \sigma_1 + \sum_{i-1}^{p} \sigma_{1i} \Delta LNRGDP_{t-i} + \sum_{i-1}^{p} \sigma_{2i} \Delta LNFDI_{t-i} + \sum_{i-1}^{p} \sigma_{3i} \Delta LNTO_{t-i} + \sum_{i-1}^{p} \sigma_{4i} \Delta LNENEC_{t-i} + \sigma_5 ECT_{T-1} + v_{1t} \quad (7)$$

$$\Delta LRGDP_t = \theta_1 + \sum_{i-1}^{p} \theta_{1i} \Delta LNRGDP_{t-i} + \sum_{i-1}^{p} \theta_{2i} \Delta LNFDI_{t-i} + \sum_{i-1}^{p} \theta_{3i} \Delta LNTO_{t-i} + \sum_{i-1}^{p} \theta_{4i} \Delta LNENEC_{t-i} + \theta_5 ECT_{T-1} + v_{2t} \quad (8)$$

The null hypotheses for the short-run Granger causality in the energy consumption equation is given by H_0: $\sum_{i-1}^{p} \sigma_{1i}=0$, H_0: $\sum_{i-1}^{p} \sigma_{4i}=0$. The null hypotheses for the short-run Granger causality in the real GDP equation are given by H_0: $\sum_{i-1}^{p} \theta_{1i}=0$, H_0: $\sum_{i-1}^{p} \theta_{4i}=0$. The long-run causality in both equations is given by the coefficients of ECT_{t-1}, that is σ_5 and θ_5 which are supposed to be negative and significant from a theoretical perspective.

3.3 Data sources

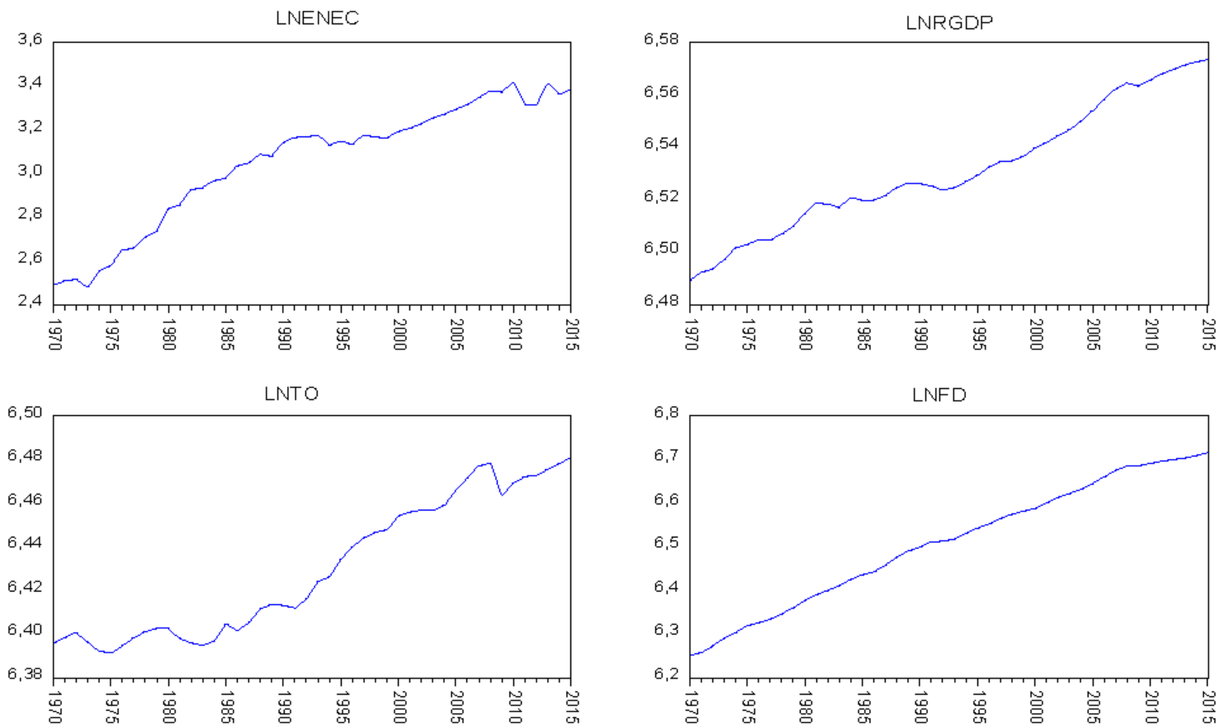
This study utilised the annual time-series data, covering the period 1970 to 2015. The data used in the study were obtained from the World Bank Economic Indicators. Additional data was obtained from the Reserve Bank of South Africa and Statistics South Africa. The next section discusses the results obtained.

4. DISCUSSION AND ANALYSIS OF RESULTS

4.1 Non-stationarity tests

The first step taken in the estimation of the results was to draw some trend diagrams for the variables that were used in the study. Figure 1 shows that all the variables are trending upwards which suggest that all the variables may be stationary after differencing. These informal test results are corroborated by carrying out the formal Augmented Dickey Fuller (ADF) and Phillips Perron (PP) tests whose results are reported below.

Figure 1: Trend diagrams of the key variables



The study used the Augmented Dickey-Fuller and Phillips-Perron (PP) tests to test for non-- stationarity. The results of the non-stationarity tests on all variables are presented in Table 1. The non-stationarity test results show that all the variables were confirmed stationary after differencing them once. Although the ARDL test does not require the pre-testing of variables to be done, the unit-root tests provide guidance as to whether ARDL procedure is applicable or not, as it is only applicable for the analysis of variables that are integrated of orders not more than one. In this case, the variables are all integrated of order 1. Therefore, the ARDL bounds testing procedure can be performed.

Table 1: ADF and PP unit root tests

Variable	Model	Level of test: Level	Level of test: First difference
Augmented Dickey Fuller (ADF)			
LNENEC	Intercept	0.527971	-8.221599***
	Trend and intercept	-1.195142	-8.794058***
LNRGDP	Intercept	0.976570	-4.407913***
	Trend and intercept	-1.914699	-4.612251***
LNTO	Intercept	1.262935	-5.704101***
	Trend and intercept	-1.648007	-5.844645***
LNFD	Intercept	0.016762	-3.546489***
	Trend and intercept	-1.475380	-4.276235***
Philip-Perron (PP)			
LNENEC	Intercept	-2.233257	-7.991570***
	Trend and intercept	-1.290618	-8.767155***
LNRGDP	Intercept	-0.288744	-4.555684***
	Trend and intercept	-1.595113	-4.488563***
LNTO	Intercept	0.370670	-5.648522***
	Trend and intercept	-2.221615	-5.719982***
LNFD	Intercept	-2.884807*	-3.942720***
	Trend and intercept	-0.032706	-4.643358***

Note: *** and * denotes significance at 1%, and 10% respectively.

4.2 Cointegration analysis

The cointegration test under the bounds framework involves the comparison of the F-statistic against the critical values for a given sample size. The bounds F-test for cointegration is performed to ascertain the possible existence of any relationship between the variables of interest. The results reported in Table 2 show the cointegration relationships for both energy consumption and economic growth. In both functions, the calculated F-statistic is found to be higher than the upper bound critical value at 10% and 1% significance levels in the multivariate Granger causality model. This implies that the null hypothesis of no long-run relationship between the dependent variable and the independent variables can be rejected at the respective significance levels. The cointegration results for the Bounds F-test suggest that there are two cointegrating vectors in the Granger causality system.

Table 2: The Bounds test for Cointegration

Dependent variable	Function		Computed F-Statistic
LNENEC	F(LNENEC|LNGDP, LNTO, LNFD)		7.7645***
LNGDP	F(LNGDP|LNENEC, LNTO, LNFDI)		5.5748***
Critical bounds			
10%		**1%**	
I(0)	I(1)	I(0)	I(1)
2.37	3.20	3.65	4.66
2.37	3.20	3.65	4.66

1.3 Analysis of causality tests based on error-correction models

Having found that there is cointegration in the variables of interest in the Granger causality model, the next step is to test the causality between the variables by incorporating the lagged error-correction term into the relevant regression equations, that is, equations (7) and (8) above. The long-run causality in this instance is examined through the significance of the lagged error correction term. Additionally, the short-run significance is ascertained by looking at the significance of the F-statistics of the lags of the individual explanatory variables using the Wald test.

Table 3: Results of Granger causality tests

Dependent Variable	**Short run (F-Statistic Probability)**		**Long run (t-statistics)**
	ΔLNENEC	ΔLNGDP	ECT_{t-1}
ΔLNENEC	-	1.791623 (0.1621)	-0.33064** (-2.0926)
ΔLNGDP	2.447294** (0.0325)	-	-0.091390* (-1.8331)

Note: ** and * denotes significance at 5% and 10% levels of significance, respectively

The short-run results reported in Table 3 reveal that there is unidirectional causality running from energy consumption to economic growth at 5% level of significance. These results corroborate findings by Odhiambo (2010), Lin and Wesseh Jr. (2014), Menyah and Wolde-Rufael (2010) and Kumar *et.al* (2015).

Long-run causality between the dependent variable and the independent variables is given by the coefficient of the lagged error-correction model. In Table 3 the signs of the estimates of lagged error-terms (ECT_{t-1}) in both the energy consumption and economic growth equations are both negative and statistically significant at 5% and 10% levels of significance respectively. The coefficient of ECT_{t-1} in the energy consumption equation is -0.33064. This means that energy consumption adjusts at the rate of 33% towards its long-run equilibrium, which implies that it will reach its full equilibrium after 4 years. In the same vein, economic growth adjusts towards its long-run equilibrium at the rate of 9.1% per year, which implies that it will take about 12 years to reach its full equilibrium. These results confirm the fact that there is long run causality between energy consumption and economic growth in South Africa. The long run results confirm findings by Sebri and Ben-Salha (2014). However, the current results are at variance with findings by Keho (2016) and Aïssa et al. (2014) who found no causality between energy consumption and economic growth

In summary, we found that although there is unidirectional causality running from energy consumption to economic growth in the short-run. We also found that there is long-run bidirectional causality between the two variables as indicated by the coefficients of the error correction terms which are found to be negative and significant (as theory predicts).

4.4 Robustness of the results

Diagnostic tests of the UECM reported in Table 4 revealed an absence of major diagnostic problems in both the energy consumption and economic growth equations. The Ramsey RESET test indicates an absence of the general specification error. The Jarque-Bera test for normality confirms residual normality. The Breusch-Godfrey LM test does not reject the null hypothesis of no serial correlation. The B-P-G and ARCH tests for heteroscedasticity reject the presence of heteroscedasticity.

Table 4: Specification and diagnostic tests for long-run ENEC and RGDP equations

Diagnostic test	**Equation (selected model**	
	ENEC (4, 3, 4, 0)	RGDP (3, 1, 0, 1)
Ramsey RESET test (2)	1.8406(0.1865)	0.02280(0.8680)
Jarque-Bera test	1.0525(0.5908)	1.47181(0.4790)
Breusch-Godfrey LM test	4.4205(0.1097)	1.70551(0.4262)
B-P-G heteroscedasticity test	16.131(0.3054)	9.94169(0.2691)
ARCH test (2)	1.1897(0.2754)	0.02980(0.8629)

Note: Numbers in brackets are the p-values

The models also applied the CUSUM and CUSUM of squares to check the stability of the energy consumption and economic growth functions. The model appears to be correctly specified and generally stable as neither the CUSUM nor the CUSUM of squares exceeded the bounds of the 5% level of significance as shown in figures 2 and 3. The same diagnostic tests applied to the error correction models estimated and the results were equally as good as the ones described here. In summary, all the robustness checks reveal that both energy consumption and economic growth functions estimated are robust and reliable.

Figure 2: Plots of CUSUM for the energy consumption equation

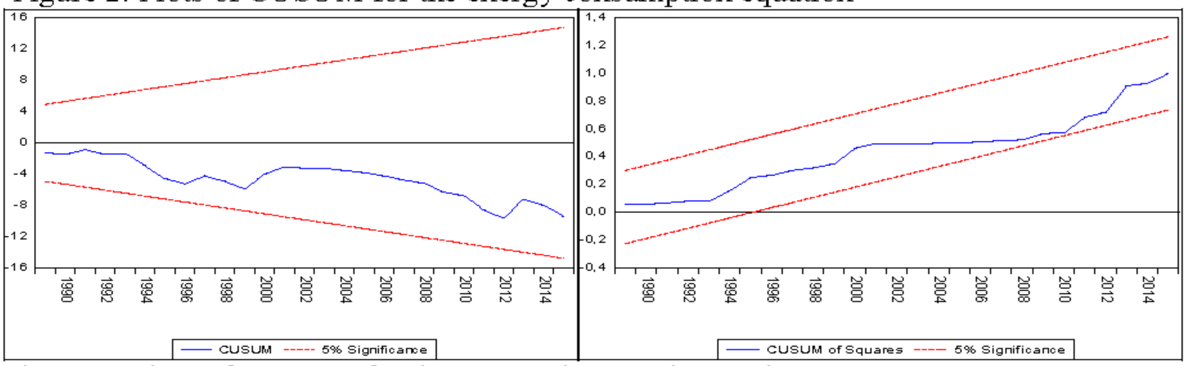
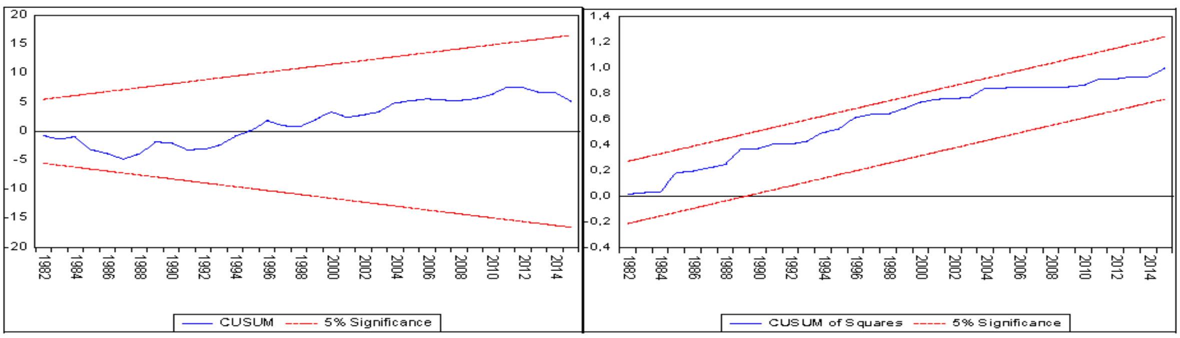


Figure 3: Plots of CUSUM for the economic growth equation



5. CONCLUSIONS AND RECOMMENDATIONS

From the results summarised in section 4, we first conclude that there is unidirectional causality running from energy consumption to economic growth in the short-run. Second, we conclude that there is long-run causality between the dependent variables and the independent variables in the error-correction equations estimated. This means that the long- run relationships among the variables in the two equations, are validated implying that there are processes of monotonic convergence to the equilibrium path of energy consumption and economic growth in South Africa. In other words, the empirical results fully support a positive long-run cointegrating relationship between real economic growth and energy consumption in South Africa. Despite the fact that the research found that there is unidirectional causality running from energy consumption to economic growth in the short-run, there is long-run bidirectional causality between the two variables as indicated by the coefficients of the error correction terms which were found to be negative and significant as theory predicts. This means that reducing energy consumption adversely affect real economic growth in both the short- and the long-run. These results imply that since energy consumption influences real economic growth both in the short and long run, South Africa should adopt a more vigorous energy policy since any attempt at energy conservation through reforming energy price policies will have damaging repercussions on economic growth.

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